A STUDY OF THE

DUST AND RELATED FACTORS

IN THE ZINC AND LEAD MINING INDUSTRY

OF OKLAHOMA

OKLAHOMA STATE HEALTH DEPARTMENT

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G. F. Mathews, M. D., Commissioner

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By

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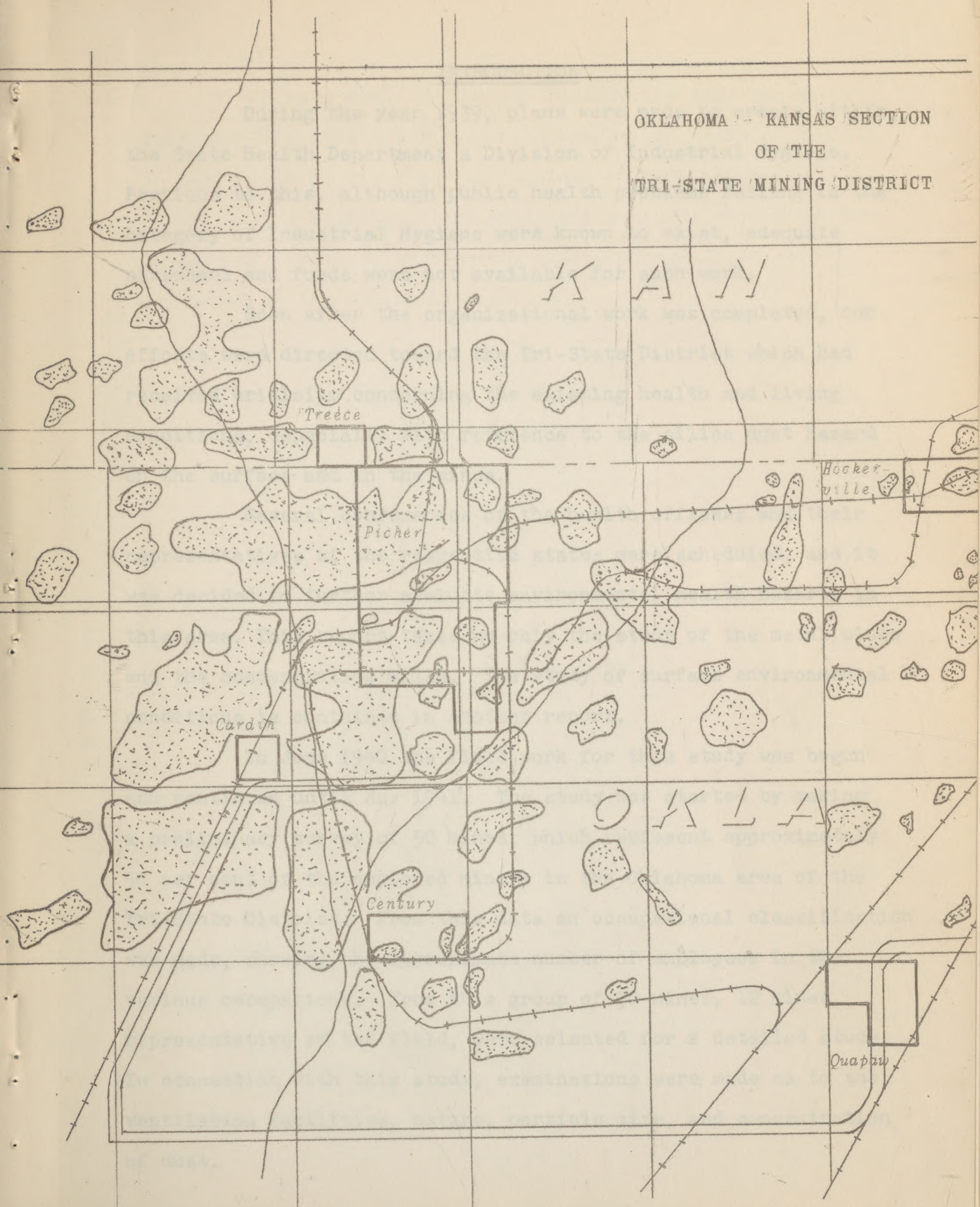
[1940]

DIVISION OF INDUSTRIAL HYGIENE

BUREAU OF PUBLIC HEALTH ENGINEERING

H. J. Darcey, Director


OKLAHOMA - KANSAS SECTION
OF THE
TRI-STATE MINING DISTRICT
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INTRODUCTION

During the year 1939, plans were made to create within the State Health Department a Division of Industrial Hygiene. Previous to this, although public health problems falling in the category of Industrial Hygiene were known to exist, adequate personnel and funds were not available for such work.

Soon after the organizational work was completed, our efforts were directed toward the Tri-State District which had received criticism concerning the existing health and living conditions, especially with reference to the silica dust hazard on the surface and in the mines.

Several conferences of the health officers and their representatives of the respective states were scheduled, and it was decided to further evaluate environmental health hazards in this area. This report takes up only the study of the metal mines and the concentrating mills. The study of surface environmental conditions is contained in another report.

In June 1940 the field work for this study was begun and continued until May 1941. The study was started by making a preliminary survey of 50 mines, which represent approximately 50 per cent of the employed miners in the Oklahoma area of the Tri-State District. From this data an occupational classification was made, showing the approximate number of employees in the various occupations. From this group of 50 mines, 12 mines, representative of the field, were selected for a detailed study. In connection with this study, examinations were made as to the ventilation facilities, nature, particle size, and concentration of dust.

Also a study of the gas hazards was made immediately following blasting and during mine operations. A brief section on sanitation in the mines is included in this report.

The results of the engineering study, with a general summary of findings, conclusions and recommendations, are presented in the following sections.

GENERAL PROCEDURES

Nature and Scope of Study

The environmental study of the Tri-State Zinc and Lead Mines was initiated by making a preliminary survey of 50 mines operated by 25 companies and involving approximately 2,000 workmen. These 2,000 workmen represented approximately 50 per cent of the mine workmen employed in the Oklahoma area of the Tri-State District. The preliminary survey also included 24 concentrating mills operated by 22 companies and involving approximately 600 workmen. These 600 workmen represented approximately 50 per cent of the mill workmen employed in Oklahoma. The preliminary survey consisted mainly of an occupational analysis of the mine and mill population to give an estimate of the percentage of occupational distribution. Once this was arrived at, the total number of samples to be collected was distributed to conform to the proportional number of workmen in various occupations. The study consisted of sampling and analysis of the atmospheric dust, gases, and the determination of other potential health hazards.

The field study was continued over a period of one year to permit the determination of the effect of various seasonal factors on the working environment.

Methods and Instruments

Dusts: To evaluate an occupational dust exposure, the amount of dust suspended in the air breathed and the physical and

chemical characteristics of this dust must be determined. In measuring the amount of dust to which workmen in various occupations were exposed, dust samples were collected with a commercial modification of the Bureau of Mines Midget Impinger apparatus (1), and were counted by the Public Health Service technique (2). The Dunn counting cell was used.

Samples of settled dust from mills were analyzed by chemical and petrographic methods for total and free silica content (3). Samples of atmospheric mine dust were collected with the electrostatic precipitator and analyzed by the x-ray diffraction method for free silica and lead content.*

To determine the size distribution and hygienic importance of the dust, a sufficient number of the particles collected in the impinger tubes were measured by the technique described by Chamot and Mason (4).

Average dust exposures associated with each occupation were estimated by weighting the dust counts made on samples representing the various activities in the respective occupations, as described in Public Health Bulletin No. 217 (2).

Gases: Mine gases were collected in the Bureau of Mines standard vacuum flasks and analyzed through the courtesy of the U. S. Bureau of Mines at their Pittsburgh Laboratories (5). No field determinations of gas concentrations were made.

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* These analyses were made by the U.S. Bureau of Mines through the courtesy of Doctor H. H. Schrenk.

Psychrometric Determinations: Temperature and humidity determinations were made with the standard sling psychrometer. Air movement was studied with the aid of a thermo-anemometer and a vane anemometer.

RESULTS OF METAL MINES STUDY

As perviously mentioned, the preliminary survey covered 50 mines. A comparison of the 50 mines surveyed, with the 12 of these mines selected for detailed study, is given in Table I to show that the sample selected was representative. The mines studied were divided into two general groups: One group included those mines where routine dust sampling services had been in practice for an appreciable time; and the other group included those mines which had not had this service. Mine workers were classified, by occupation, into four general groups as follows: first, office and general supervision; second, face operations; third, transportation, and fourth, maintenance and construction. For each of the two groups of mines, approximately the same number of samples were collected; however, the number of samples representing exposures of the different occupational groups varied in close proportion to the percentage of labor distribution.

Geography and Geology

The topography is characterized by a generally flat or slightly rolling prairie plain drained toward the south by the Neosho River on the west, the Spring River on the east, and by numerous smaller streams. East of Spring River, the foothills

of the Ozark Uplift are in evidence. The surface slope is generally to the south and west and somewhat less than the dip of the sub-surface strata. Shales and limestones outcrop in most of the western part of the area, and cherts and limestone in the east.

The concentrations of sphalerite and galena occur irregularly in the Boone Formation of Mississippian age. This massively bedded formation consists of highly brecciated chert and limestone with jasperoid, dolomite, calcite, marcasite, sphalerite and galena as vein material. In some places the ores occur below this highly brecciated portion of the formation in a "sheet ground," which consists of relatively thin beds of chert and jasperoid. Here the sphalerite and galena occur in small caverns or are disseminated in jasperoid.

The ore occurs from 200 to 400 feet deep and is mined by an irregular system of drifts and open stopes. At present the sphalerite recovered averages about 5 per cent, and the galena less than 1 per cent of the rock hoisted.

Mining Methods

The ore bodies in this district are outlined by churn drilling, and reached by means of a single compartment shaft usually 6 feet by 6 feet, or 5 feet by 7 feet. Upon reaching the desired level, the ore body is exploited by means of irregular horizontal drifts or chambers in which the "breast and bench stoping" method of mining is employed. The mined out areas are left

open, pillars of various thicknesses and irregular distribution being left to support the overlying formations. Further development is done by means of pull drifts to other shafts or ore bodies on the same level, and by raises and winzes driven to detached ore bodies at higher or lower levels.

The ore is broken by a series or "round" of holes wet-drilled with an air-driven rock drill and loaded with dynamite, which is exploded by fuse after the shift. Because of the hardness and strength of the ore, unusually large charges are necessary. Loading is done mechanically by drag loaders and manually with shovels. The ore is transported in "cans" mounted on small trucks and run on narrow gage railways by electric motors or drum hoist and wire rope, or mules. These cans are hoisted to the surface individually by means of a drum hoist and free-swinging cable, emptied into a hopper, and returned underground.

Occupational Analysis and Description of Chief Occupations

In studying the various occupational exposures, detailed studies of activities inherent to each of the occupations were made. For example, it was found that the occupations of machine man and helper could roughly be divided into three groups of activities: The first group of activities after going underground consisted of wetting the muck pile, bringing drilling equipment to the working face, and making necessary pipe and hose connections. These activities required an average expenditure of

time of about two to two and one-half hours. The next group of activities included the actual drilling operations and lasted, on the average, for four to four and one-half hours. The last group of activities in this occupation, lasting approximately one to one and one-half hours, consisted of removing drilling equipment, loading holes, and lighting the fuses immediately before returning to the surface. As a rule, three different dust exposures were associated with these three different groups of activities, and consequently, an average dust exposure for the full working day was computed by weighting these three exposures with respect to the time spent in each group of activities.

The occupation of shoveler, similarly, was comprised of activities that presented various amounts of dustiness. The shoveler's time is spent in hand-shoveling the ore into cans, pushing the loaded ore cans to the lay-by (siding) and pushing empty cans back to the working face. The weighted average dust exposure was determined for this occupation on the basis of the amount of time spent at each of these activities. Generally, lower average dust exposures were encountered during the transportation operation than during the actual loading. Following is a list and description of the chief occupations:

<u>General manager and superintendent</u> supervise and are responsible for all mining and milling operations.

<u>Foreman and cokey herder</u> supervise all underground operations, including the responsibility for safety and health conditions.

Machine man and helper are engaged in drilling with an air-driven rock drill mounted on posts and using a detachable "cross bit" and steel shank through which water is run to the end of the hole. These operations are carried on at the working face whether it is in the heading, stope, raise, floor, or roof, and also include loading and shooting the "round" of holes.

Mechanical loader operator operates slusher or scraper loaders.

Roof trimmer inspects and trims the roofs of the mine workings.

Shoveler and bruno man load the broken rock at the bottom of the stope into cans or cars with scoops or by hand and tram to the lay-by. The bruno man clears the stope and floor. This operation is usually carried on back of and simultaneously with the drilling operation.

Hoisterman (derrick) operates the machinery for lifting the cans in the man or dirt shafts. Electric hoists are primarily used, some hoists were operated by air, or gasoline motors.

Hooker and bumper, the hooker at the bottom of the shaft replaces empty cans with loaded cans on the hoisting cable. The bumper trams loaded and empty cans between switch or lay-by and the bottom of the shaft.

Hopperman fills can from underground hopper and trams to nearest switch or lay-by.

Incline hoistman operates hoists (usually air) to bring cans to main transportation levels.

Mule driver trams cans from face switch or lay-by to shaft.

Motor man trams cans from face switch to shaft.

Rope rider spots cans under mechanical loader and rides train to and from shaft.

Blacksmith does general maintenance work and repairs mining equipment and in many instances sharpens drill steel.

Carpenter does construction and repair work, mostly underground.

Pumpman operates and maintains both underground and surface pumps.

Repairman, general roustabout.

Sprinkler, ordinarily a two-man crew wetting down haulage-ways and working faces either on or between regular shifts.

Trackman, maintains trackage.

Psychrometric Conditions

Temperature and humidity determinations were made at sampling locations and at other points which would give a general picture of underground conditions. Some measurements were made of air movements at the working face and others were made near shafts to estimate the amount of natural or artificial ventilation. From these data, the effective temperatures in the various workrooms were determined.* Air temperatures which were recorded at the working face are shown in Table II. They

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* Effective temperature may be defined as that temperature of saturated air which, moving at a velocity of 15 to 25 feet per minute, would produce the same sensation of warmth or cold as that produced by the combination of temperature, humidity, and air motion under observation.

varied from a maximum of 76.5° F., to a minimum of 46.0° F., with a humidity variation of 90 plus or minus 10 per cent, as shown in Table II. Air velocity measurements made at the working face varied from practically still air to a velocity of from 50 to 75 feet per minute. The calculated effective temperatures varied from 42 to 75° F., with an average of 59° F.

The majority of these effective temperature determinations fell within the comfort zone for men performing strenuous work, and conclusive data is not available showing that the higher effective temperatures encountered are detrimental to health, although they may be uncomfortable. However, it should be remembered that high effective temperature may be lowered by increased air velocity and that the effect of working in hot atmospheres may be largely mitigated by providing sodium chloride (common salt), and a plentiful supply of drinking water.

In the majority of cases, these effective temperatures were based on air movement of 25 feet per minute or less, recorded at the working face. Natural ventilation is relied upon in most mines; however, in several instances fresh air is forced into the mines by blowers located over abandoned shafts and drill holes. Usually this supply of fresh air is distributed to the working faces by underground booster fans and the use of canvas sails.*

In stopes to which air is not supplied under pressure, local ventilation is sometimes attempted by placing blowers near

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* The term "sails" as used in the Tri-State Mining Area, applies to flexible cloth-tubing used for ventilation purposes.

the working face. This use of blowers with both the inlet and outlet at or near the face has, in a few instances, improved the working conditions by lowering the dust concentrations, but in most instances encountered in this study, no perceptible reduction was noted since the blowers merely stirred up eddy currents without removing dusty air from the area.

As mentioned in the discussion of the plan and scope of this study, it is necessary to determine several factors in evaluating a dust hazard. These factors include mineralogical composition, size of dust particles, concentration of the dust in the atmosphere, and the duration of exposure during the working day. All of these factors have been studied in detail and the results of this study are summarized in the following sections.

Atmospheric Dust

Siliceous Content of Dust: Ten dust samples were collected and analyzed for silica content. A summary of the percentage of total and free silica in these samples is given in Table III, together with notes as to source and method of analyzing each sample. Four settled dust samples were collected in concentrating mills in the vicinity of the primary crushers. These were analyzed chemically for total silica content and petrographically to determine the percentage of free silica. Five dust samples were collected with the electrostatic precipitator in mine air during normal operations while the men were at the working face. These samples were analyzed by the x-ray diffraction method, since the particles of dust suspended in the

air were too fine to permit analysis by a petrographic method. The precipitator sampling time varied from four to eight and one-half hours, in atmospheres containing 2 to 10 million particles per cubic foot of air. The total weight of the dust samples collected varied from 18 to 250 milligrams.

The figures for the free silica content of dust include both quartz and chalcedony. The free silica reported on settled dust samples varies from 45 to 65 per cent. The variation is much larger in the reported percentage of free silica in the air-borne mine dust samples analyzed by the x-ray diffraction method; namely, from 32 to 71 per cent. No correlation of the different percentages was justified with respect to various occupations other than as is indirectly indicated by the values for mine haulage-ways and working faces, these being 39 and 62 per cent respectively, since wide variations in the silica content of the rock may occur not only between different mines but also in different sections of the same mine.

Size of Dust: Particle size determinations were made on dust from 6 impinger samples secured in a water-collecting medium in 2 different mines. The median particle size (1.1 microns) was obtained from the curve shown in Figure 1 and Table IV, representing 1,000-particle size measurements. Approximately 43 per cent of the dust is less than one micron, and over 95 per cent of the dust is less than 3 microns in average diameter; consequently, we can assume that practically all of the dust occurring in the working atmosphere of these mines is of a size which will settle very slowly from the air and will very readily enter the deepest lung tissues.

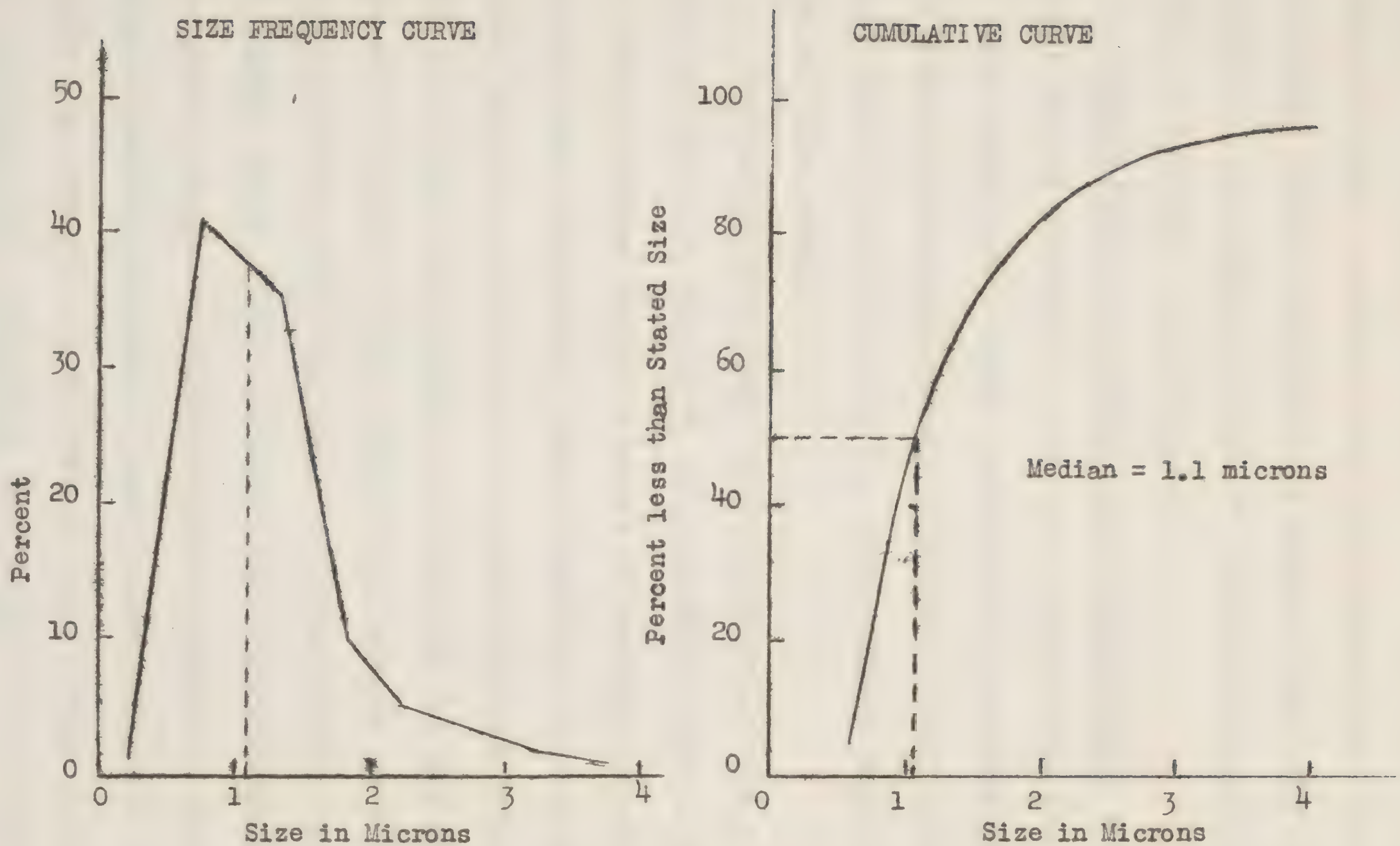

Fig. 1 - Particle Size Distribution of Metal Mine Dusts

Particle size determinations made on samples collected at crushing and ore transfer stations in a concentrating mill are shown in Table IV. The median size of the particles collected at these locations was 0.95 microns and 2.6 microns respectively. While the latter is larger than that of the dust in underground atmospheres, most of these particles were within the range of hygienic significance.

Occupational Dust Exposures Underground: Approximately two-thirds of all workers in the mines come under the group heading of face operations, which includes the occupations of machine man and helper, mechanical loader operator, roof trimmer, and shoveler; hence, two-thirds of all dust samples collected represent exposure of this group.

The weighted average dust exposure of metal mine employees is shown in Tables V, VI, and VII, both as an average for all mines studied and on a basis of average exposure in the two mining classifications: those receiving routine air hygiene inspection services; and those not receiving such routine services, respectively. The total number of employees in the mines covered, is shown on the basis of the preliminary survey as well as for the groups studied since the study of 12 mines was representative of this larger group. It is evident that conditions are better in those mines receiving routine services than in those where no regular attention is paid to dust concentrations. This is especially illustrated in the case of face workers, where the average exposures for this group as a whole is 5.8 million particles of dust per cubic foot of air, and increases to 6.4 million in the unserviced mines and drops to 5 million in the

serviced mines, and is even more dramatically illustrated in the case of machine man and machine man helper, where, although the average exposure for the 12 mines was 6 million, it increased to 7 million in the unserviced mines and dropped to 4.3 million in those mines receiving routine dust counting services. Another example of this difference is in the case of the rope rider, whose average exposure varies from 10 million in the group not serviced to 5.6 million in the group having had routine dust counting services.

It is evident that reduction in dust exposure in the section classed as face workers, which produces the majority of dust, will practically solve any existing dust problems in Oklahoma metal mines.* Not only is this the only section having any large number of employees exposed to moderately high dust concentrations, but also this section includes over 70 per cent of the total number of employees in these mines. The occupations of hopper man and rope rider in the transportation section and the occupation of track man in the maintenance and construction section are the only other ones showing average exposures to concentrations above 5 million particles of dust per cubic foot of air. However, it must be remembered that maintenance and service employees have a widely varied exposure and their average dust exposure will depend upon the general condition of the mine. Any reduction in dust concentrations caused by production operations will decrease the exposure of transportation and maintenance workers.

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* The proper control of mine dust at its major point of generation, namely, face operations, will obviously reduce dangerous dust concentrations in other parts of the mine.

The weighted average dust exposure for each occupational classification was determined individually for each of the 12 mines studied. The maximum and minimum values encountered in this series of mines have been summarized in Table VIII. This table was not intended to imply that any one mine has been chosen as an example of maximum or minimum conditions, although considerable variation was noted in the average conditions between different mines. This table is intended to indicate that practically all operations in this mining field are being conducted in some of the mines, under conditions which can, according to our present knowledge of the effect of atmospheric dust, be considered safe working conditions; and that the application of the control methods used in these mines to the other mines should eliminate any question of a dust hazard in this area. It is interesting to note that the only major occupational classification which was not found to be operating in any mine with an average dust exposure of less than 5 million particles per cubic foot of air was the mechanical loading operation, which is a notorious dust producer. However, the appreciable reduction in dust in one mine to a concentration of 6.4 million particles per cubic foot must be commended. It should also be noted that the dust concentrations in all of these mines compared favorably with concentrations reported in past studies in other areas in the United States (6).

Occupational Dust Exposures in Concentrating Mills: The results of determinations of dust concentrations in concentrating mills have been summarized in Table IX. Eight

concentrating mills were studied, of which 4 were running mine ore, and the other 4 were running tailings. The various occupations have been separated into 3 general sections; namely, primary crushing operations, wet crushing and grinding, and wet concentration (by sludge-tables, jigs, or froth flotation). The average dust exposure encountered in the last 2 sections which are essentially wet processes, were all below 3 million particles per cubic foot of air; however, the weighted average dust exposure of primary crusher operators was 12.8 million particles per cubic foot. This average is the arithmetic mean of the 12 samples representing this section. Individual samples showed a variation from 5 to 20 million particles per cubic foot, approximately. Since this is the only occupation in the crushing plant that showed appreciable dust exposure, it is felt that control of this process by the methods recommended in a following section should eliminate any potential dust hazard in the concentration of ore. It was noted that filter-type respirators were usually worn by crusher operators. While this form of personal respiratory protection is satisfactory under optimum conditions of maintenance and use, it should be possible to reduce dust concentrations in this department by application of positive control measures (wet methods or local exhaust ventilation) to a level where the continuous use of masks would not be necessary.

<u>Control Practices</u>: Dust control in the mines was usually practiced by two methods: first, use of water as in wet drilling, sprinkling of haulage-ways, wetting muck piles, and

spraying the muck during mechanical loading operations; and second, natural and mechanical ventilation. Muck piles were usually wet down by the machine man's helper and shovelers before other operations were begun. Water sprays were used in connection with mechanical loading operations, both at the loading and discharge ends. In a few instances it was noted that mechanical ventilation was practiced to supplement natural ventilation. In the primary crushing occupations in mills, the use of respirators was found to be a general practice. In the grinding occupations, wetting methods and local exhaust were used.

Gas Concentrations

The results of analyses of gas samples taken in the various mines studied are summarized in Tables X and XI. It will be seen from these tables that all air analyses fell within reasonably normal limits with regard to carbon dioxide, oxygen, and nitrogen content. None of these mines can be classed as deep mines since all mining operations are at an elevation close enough to sea level so that the normal variations in the partial pressure of oxygen probably would have no physiological ill-effects.

These mines do not come under the Bureau of Mine's classification of gassy mines; however, noxious gases are produced when high explosives are used. It was the usual policy to fire explosives at the end of the working shift and not to return to the working faces until after these gases had been dissipated; i.e., at least four hours interval between double shifts. Tests for the presence of oxides of nitrogen and for carbon monoxide were made at various intervals after blasting.

These tests showed, in several instances, the presence of oxides of nitrogen as long as 15 hours after blasting, but no concentrations were detected, during the normal working period, which could be considered of a toxic nature. The concentration of oxides of nitrogen decreased progressively with increasing intervals after blasting.

The concentration of carbon monoxide was determined on 73 samples. Seventeen of these samples showed the presence of this gas, but none of the samples showed more than .01 per cent by volume, which is within the safe limit for prolonged exposure (7). However, the evidence that this gas may occur in these mines should be given due weight and care should be taken not to enter dead ends or working places which do not have adequate ventilation without making proper tests for this gas.

For the purpose of comparison of the data gathered in this study with data previously gathered regarding gas concentrations in mines in the Tri-State District, the work of Tomlinson and Berger, U. S. Bureau of Mines, in 1937, has been summarized in Table XII (8). It will be noted that while the difference between gas concentrations determined on these two studies are probably within range of sampling variations and cannot be considered as highly significant, the maximum concentrations of carbon monoxide and of oxides of nitrogen encountered in our study were lower than those taken in 1937.

<u>Atmospheric Lead Concentrations</u>

The analyses of 6 samples of dust collected from the working atmosphere in metal mines with the electrostatic precipitator and analyzed by the x-ray diffraction method (11)

showed that the lead concentrations varied between .014 and .098 milligrams of lead per 10 cubic meters of air. Two of these samples were collected in mine haulage-ways and 4 were collected at the working face. The maximum and minimum values for these two groups of samples are shown in Table XIII. Due to the limited number of samples, average values would have no appreciable significance but none of these samples showed more than .1 of a milligram of lead per 10 cubic meters of air, and all of them are well below the suggested maximum permissible value of 1.5 milligrams of lead per 10 cubic meters of air, which has been recommended by the Public Health Service for the lead storage battery industry (9). It has also been shown by Fairhall (10) that the solubility and toxicity of lead sulphide is probably less than that of the lead oxides used in the storage battery industry.

Sanitation

This phase of the report was prepared, not from a detailed study, but rather from observation of the methods employed for handling sanitary facilities in the several mines.

Generally, drinking water was supplied in some of the mines when located near a public water supply, by plumbing throughout the working places in the mines. Where this was not possible or not practiced, drinking water was supplied in one or another of several ways: usually open barrels of two to five gallons capacity; this method involved the use of a common drinking cup, or in the case of small sized barrels or kegs generally no cup was used, merely the hole in the keg placed to the mouth.

In many mines, proper methods of waste disposal were lacking. The box and can type privy was noted quite frequently; however, proper maintenance of this method was found lacking in the majority of cases.

SUMMARY

This is a report of the study of the working environment in 12 mines and 8 mills in the Tri-State District, which were selected to represent all important variations in working conditions. The Oklahoma mining field is part of the Tri-State Lead and Zinc Mining District, in which lead and zinc sulphide ores are found in a gangue consisting primarily of thoroughly silicified limestone and dolomite.

Psychrometric conditions were evaluated by determining the variations in temperature, humidity, and air movement. Dry bulb temperatures ranged between 46.0 and 76.5° F; relative humidity between 83.0 and 100.0. Air velocities were generally low and averaged less than 50 feet per minute; consequently, "effective temperatures" which are a function of temperature, humidity, and air motion, occurred between values of 42 and 75° F. The free silica content of settled dusts collected in mills ranged from 45 to 65 per cent. The free silica content of air-borne dust collected underground ranged from 32 to 71 per cent. Particle size measurements made on underground air-borne dust samples showed a mean particle diameter of 1.1 microns; 95 per cent being below 3 microns. Particle size determinations were also made on mill dust samples, one collected near the primary crushers, showing an average diameter

of 0.95 microns, and another sample collected near the belt transfers, showing the average particle size to be 2.6 microns.

It was found that in the mines studied, 8 per cent of the workers in the mines that had had routine dust sampling services had an average dust exposure greater than 5 million particles per cubic foot. In those mines that had not had this routine service, 72% of the workers were exposed to an average dust exposure greater than 5 million particles per cubic foot. This wide variation in per cent of workers exposed to greater than 5 million particles per cubic foot in the two groups is evident upon examination of Tables VI and VII. Table VI shows the dust concentration for the group that has had routine dust counting services and it should be noted that the occupations of machine man and helper, and shoveler (the largest occupational groups) both have an average dust concentration below 5 million particles per cubic foot. From Table VII, a similar examination reveals that these same occupations (machine man and helper, and shoveler), comprising approximately 68% of the workers, both have an average dust concentration above 5 million particles per cubic foot. All concentrating mill workers, with the exception of those performing primary crushing operations, were found to have an exposure to less than 3 million particles per cubic foot, representing 84% of the mill workers. Primary crusher operators, practically all of whom wore respirators, worked in an environment of approximately 12.8 million particles per cubic foot, representing 16% of the mill workers.

Dangerous concentrations of harmful gases were not encountered.

Atmospheric concentrations of lead were all below 0.10 milligrams per 10 cubic meters of air; consequently, no evidence of the existence of an atmospheric lead hazard was found.

Brief consideration given to the condition of sanitary facilities, both in mines and mills, showed that in a great many instances poor sanitary facilities existed.

CONCLUSIONS

The same types of control measures are used throughout the area, although the methods of application may differ in different mines. This study has shown that a few occupations were continually associated with relatively high concentrations. These occupations (mechanical loader operator, roof trimmer, rope rider) should receive special attention in the matter of dust control in all mines where these occupations occur. Likewise, the machine man and helper, and shoveler in those mines that have not had routine dust sampling service, should receive special attention in the matter of dust control. Relatively high dust concentrations were also found in the hopper and crusher section of the concentrating mills, and the present practice of using approved respirators in this section has probably minimized the possibility of any damage. However, since the continuous use of a respirator throughout the working day is difficult to secure, the control or collection of the dust at its point of generation by improvement of wet methods, or the use of local exhaust ventilation, would give a more positive control of this dust hazard.

Lead concentrations found in the mine air apparently present no hazard. Likewise, toxic gas concentrations during working periods were all within safe limits, and no acute exposures should occur if a reasonable waiting period is maintained between shifts.

RECOMMENDATIONS

The present extensive use of wet methods for controlling rock dust is highly commended and should be continued. The following recommendations should be considered as essential to proper dust control.

1. Adequate ventilation for dust control should be provided at all working places. In cases where natural ventilation is not adequate, it should be supplemented with proper mechanical ventilation.

2. All drill holes should be collared wet.

3. The practice of thorough wetting down of muck piles, haulage-ways and other areas where dust is being produced, should be adopted by those operators who are not now practicing this control method.

4. Double shift operations present additional hazards, therefore, additional precautions should be taken.

5. It is recommended that the past practice of assuming a dust count of 5 million particles per cubic foot of air as the probable maximum safe concentration should be continued.

6. It is recommended that a program of frequent dust counts and affiliated tests of the working environment be instigated for those mines not now receiving such service.

7. Drinking water should be supplied in a sanitary manner from a safe source. The use of the common drinking cup should be prohibited.

Improvements in the method of handling human wastes should be made where needed.

ACKNOWLEDGEMENT

The Oklahoma State Health Department wishes to express their appreciation of the assistance rendered by the following agencies: Mine and mill owners and operators who made their properties and records available for study; U. S. Bureau of Mines and especially the valuable assistance of Doctor H. H. Schrenk, Pittsburgh Experimental Station; Division of Industrial Hygiene, National Institute of Health, U. S. Public Health Service and especially the valuable assistance of Mr. J. J. Bloomfield, Mr. R. T. Page, and Doctor F. H. Goldman; Oklahoma Department of Mines; and the Tri-State Zinc and Lead Ore Producers Association, and especially the valuable assistance of Mr. Evan Just and Mr. Fred Netzeband.

TABLE I

OCCUPATIONAL ANALYSIS OF EMPLOYEES OF TWELVE METAL MINES STUDIED COMPARED WITH OCCUPATIONAL ANALYSIS OF FIFTY METAL MINES FROM THE PRELIMINARY SURVEY

Section and Occupation	Total for study of 12 mines	Total for preliminary survey of 50 mines
Office and General Supervision:	(26)	(93)
General manager, superintendent, watchman		
Foreman and herder		
Face Operations, Underground:	(368)	(1290)
Machine man and helper	153	539
Mechanical loader operator	4	22
Roof trimmer	13	42
Shoveler and bruno man	198	687
Transportation, Underground:	(119)	(410)
Hoisterman (derrick)	23	89
Hooker and bumper	36	120
Hopperman	5	6
Incline Hoisterman	19	68
Mule driver	26	91
Motor man	5	10
Rope rider	5	26
Maintenance and Construction, Underground:	(39)	(149)
Blacksmith	6	21
Carpenter	2	13
Pumpman	4	11
Repairman	3	14
Sprinkler	6	22
Trackman	18	68
Total	552	1942

TABLE II

PSYCHROMETRIC OBSERVATIONS

IN TRI-STATE MINES

	Dry Bulb Temperature	Relative Humidity	Effective Temperature
Maximum	76.5°F	100.0%	75°F
Minimum	46.0°F	83.0%	42°F
Average	62.0°F	90.4%	59°F

TABLE III

SILICA CONTENT OF TRI-STATE DISTRICT MINE DUSTS

Location	Number of Samples	Percent Total Silica			Percent Free Silica	
		Maximum	Minimum	Average	Maximum	Minimum
Ore milling processes [1]	4	68.6	54.5	59.2	65	45
Mine haulage-ways [2]	2	Not determined			45	32
Working face [3]	3	Not determined			71	54

(1) All four samples were collected in the immediate vicinity of the primary crushers, representing settled dust, and analyzed chemically and petrographically.

(2) Both samples were collected with the electrostatic precipitator away from the immediate working face, in two different mines, analyzed by the x-ray diffraction method.

(3) All three samples were collected with the electrostatic precipitator in the immediate vicinity of the working face, in four different mines, analyzed by the x-ray diffraction method.

TABLE IV

SUMMARY OF SIZE-FREQUENCY DISTRIBUTION

OF DUST SUSPENDED IN THE AIR OF METAL MINES

Size Grouping in Microns	0.00 to .49	.50 to .99	1.00 to 1.49	1.50 to 1.99	2.00 to 2.49	2.50 to 2.99	3.00 to 3.49	3.50 to 3.99	4.00 to 4.49	4.50 to 4.99	5.00 to 5.49	5.50 to 5.99
Percent Frequency	1.5	41.2	34.3	10.3	4.9	3.5	1.5	.7	.1	.2	.4	.3

SUMMARY OF SIZE-FREQUENCY DISTRIBUTION

OF DUST SUSPENDED IN THE AIR OF CONCENTRATING MILLS

	Size Grouping in Microns	0.00 to .49	.50 to .99	1.00 to 1.49	1.50 to 1.99	2.00 to 2.49	2.50 to 2.99	3.00 to 3.49	3.50 to 3.99	4.00 to 4.49
Percent Frequency	Jaw Crusher	12	44	30	10	2	1	1		
	Conveyor Discharge	3	7	14	8	15	10	14	12	4

TABLE V

SUMMARY OF OCCUPATIONAL DUST EXPOSURE

IN REPRESENTATIVE TRI-STATE METAL MINES

Section and Occupation	Number of men employed in:*		Number of samples taken	Number of millions of dust particles per cubic foot of air (weighted average)
	50 mines surveyed	12 mines studied		
Office and General Supervision:				
General manager, superintendent, watchman	28	10	-**	0.4
Foreman and herder	65	16	-**	3.8
Face Operations, Underground:	(1290)	(368)	(224)	(5.8)
Machine man and helper	539	153	91	6.0
Mechanical loader operator	22	4	13	11.5
Roof trimmer	42	13	12	8.2
Shoveler and bruno man	687	198	108	4.7
Transportation, Underground:	(410)	(119)	(66)	(3.4)
Hoisterman (derrick)	89	23	10	0.7
Hooker and bumper	120	36	9	0.6
Hopperman	6	5	10	4.5
Incline hoisterman	68	19	12	2.4
Mule driver	91	26	7	3.3
Motor man	10	5	4	4.1
Rope rider	26	5	14	6.2
Maintenance and Construction:	(149)	(39)	(32)	(3.2)
Blacksmith	21	6	2	1.6
Carpenter	13	2	2	2.5
Pumpman	11	4	4	1.2
Repairman	14	3	2	2.1
Sprinkler	22	6	9	3.4
Trackman	68	18	13	4.1
Total	1942	552	-***	

*Approxomately 50% of the employees in this industry in Oklahoma were included in this survey.

**Number of samples not indicated since many are representative.

***Samples frequently represented more than one activity; hence, no total is given in this column.

TABLE VI

SUMMARY OF OCCUPATIONAL DUST EXPOSURE IN METAL MINES

OF THE GROUP THAT HAVE HAD ROUTINE DUST COUNTING SERVICES

Section and Occupation	Number of men employed in: 32 mines surveyed	Number of men employed in: 5 mines studied	Number of samples taken	Number of millions of dust particles per cubic foot of air (weighted average)
Office and General Supervision:				
General manager, superintendent, watchman	20	4	-*	0.4
Foreman and herder	43	9	-*	3.9
Face Operations, Underground:	(746)	(164)	(102)	(5.0)
Machine man and helper	350	77	38	4.3
Mechanical loader operator	18	4	11	11.7
Roof trimmer	33	9	9	8.6
Shoveler and bruno man	345	74	44	3.2
Transportation, Underground:	(255)	(58)	(35)	(4.1)
Hoisterman (derrick)	57	10	4	3.5
Hooker and bumper	80	20	5	1.5
Hopperman	4	2	5	5.9
Incline Hoisterman	46	12	7	2.6
Mule driver	45	9	2	3.2
Motor man	1	-	-	-
Rope rider	22	5	12	5.6
Maintenance and Construction:	(98)	(22)	(19)	(2.9)
Blacksmith	13	1	-	-
Carpenter	8	2	2	2.5
Pumpman	7	2	2	1.2
Repairman	8	3	1	2.1
Sprinkler	20	5	9	3.4
Trackman	42	9	7	2.9
	1162***	257	-**	

*Number of samples not indicated since many are representative.

**Samples frequently represented more than one activity; hence, no total is given in this column.

***These 1162 men were employed in 32 of the 50 mines included in the preliminary survey.

TABLE VII

SUMMARY OF OCCUPATIONAL DUST EXPOSURE IN METAL MINES

OF THE GROUP THAT HAVE NOT HAD ROUTINE DUST COUNTING SERVICES

Section and Occupation	Number of men employed in:		Number of samples taken	Number of millions of dust particles per cubic foot of air (weighted average)
	18 mines surveyed	7 mines studied		
Office and General Supervision:				
General manager, superintendent, watchman	8	6	-*	0.4
Foreman and herder	22	7	-*	4.8
Face Operations, Underground:	(544)	(204)	(122)	(6.4)
Machine man and helper	189	76	53	7.0
Mechanical loader operator	4	-	2	10.7
Roof trimmer	9	4	3	7.0
Shoveler and bruno man	342	124	64	5.7
Transportation, Underground:	(155)	(61)	(31)	(3.0)
Hoisterman (derrick)	32	13	6	1.0
Hooker & bumper	40	16	4	0.6
Hopperman	2	3	5	3.8
Incline hoisterman	22	7	5	2.8
Mule driver	46	17	5	3.3
Motor man	9	5	4	4.1
Rope rider	4	-	2	10.0
Maintenance and Construction:	(51)	(17)	(13)	(4.4)
Blacksmith	8	5	2	1.6
Carpenter	5	-	-	-
Pumpman	4	2	-	-
Repairman	6	-	-	-
Sprinkler	2	1	-	-
Trackman	26	9	6	5.4
Total	780***	295	-**	

*Number of samples not indicated since many are representative.
**Samples frequently represented more than one activity; hence, no total is given in this column.
***These 780 men were employed in 18 of the 50 mines included in the preliminary survey.

TABLE VIII

RANGE OF AVERAGE DUST EXPOSURES

FOR MAJOR OCCUPATIONS IN THE MINES STUDIED

Section and Occupation	Dust Concentration*	
	Maximum	Minimum
Face Operations, Underground:		
Machine man and helper	14.3	1.6
Mechanical loader operator	16.1	6.4
Roof trimmer	10.5	2.1
Shoveler and bruno man	11.1	2.0
Transporation, Underground:		
Hoisterman (derrick)	7.4	0.3
Hooker and bumper	2.9	0.6
Hopperman	20.2	3.8
Incline Hoisterman	5.2	1.9
Mule driver	3.7	2.7
Rope rider	10.0	5.0
Maintenance and Construction:		
Blacksmith	2.4	1.6
Repairman	11.2	2.1
Trackman	5.4	1.9

* In millions of particles per cubic foot of air.

TABLE IX

SUMMARY OF OCCUPATIONAL DUST EXPOSURE

IN EIGHT REPRESENTATIVE CONCENTRATING MILLS

Section	Mine Mills			Tailing Mills		
	Number of men employed*	Number of samples taken	Number of millions of dust particles per cubic foot of air	Number of men employed*	Number of samples taken	Number of millions of dust particles per cubic foot of air
Primary Crushing	200	12	12.8	-	-**	-**
Secondary Crushing and Grinding Rougher & cleaner jigs Rolls Ball mills	400	15	2.3	125	18	1.3
Wet Concentration Sludge tables Flotation plant	400	7	1.2	125	7	1.2

*An approximation
**Primary crushing operations not associated with tailing mills.

TABLE X

RELATION OF COMPOSITION OF MINE AIR

TO TIME INTERVAL BETWEEN BLASTING AND AIR SAMPLING

Time After Blasting Hrs.	Min.	Percent CO_2	Percent O_2	Percent CO	Percent N_2	Oxides of Nitrogen (p.p.m.)
0	40	.10	20.69	.00	79.15	13
1	40	.11	20.86	.00	79.03	9
3	00	.10	20.79	.00	79.11	5
4	00	.05	20.92	.00	79.03	2
5	00	.10	20.81	.00	79.09	6
6	30	.12	20.77	.00	79.11	4
7	00	.14	20.62	.00	79.24	3
0	45	.11	20.91	.00	78.98	4
2	00	.14	20.86	.00	79.00	0
3	15	.13	20.91	.00	78.96	2
4	00	.14	20.82	.00	79.04	2
5	00	.16	20.72	.00	79.12	7
15	00	.12	20.84	.00	79.04	6
15	15	.12	20.91	.00	78.97	0
0	45	.40	20.62	.01	78.97	19
1	15	.33	20.73	.01	78.93	14
2	05	.29	20.72	$<$.01	78.98	9
3	00	.26	20.68	$<$.01	79.05	7
4	15	.20	20.70	$<$.01	79.09	7
5	25	.25	20.69	$<$.01	79.05	9

TABLE XI

SUMMARY OF GAS ANALYSES

	Number of samples	Samples showing	Maximum	Minimum
Carbon Dioxide (% by volume)	73	73	0.40	0.03
Oxygen (% by volume)	73	73	20.93	20.40
Carbon Monoxide (% by volume)	73	17	0.01	Trace
Nitrogen (% by volume)	73	73	79.24	78.93
Oxides of Nitrogen (p.p.m.)	22	21	29	2

TABLE XII

SUMMARY OF SURVEY OF COMPOSITION OF MINE ATMOSPHERES AFTER BLASTING IN MINES IN THE TRI-STATE DISTRICT OF OKLAHOMA, KANSAS, AND MISSOURI BY TOMLINSON AND BERGER U. S. BUREAU OF MINES IN 1937*

	Number of Samples	Samples showing	Maximum	Minimum
Carbon Dioxide (% by volume)	76	76	1.58	0.07
Oxygen (% by volume)	76	76	20.90	17.35
Carbon Monoxide (% by volume)	76	24	0.32	Trace
Nitrogen (% by volume)	76	76	81.96	78.03
Oxides of Nitrogen (p.p.m.)	63	23	90	10

* Printed by permission.

TABLE XIII

ATMOSPHERIC LEAD CONCENTRATIONS*

IN METAL MINES

Location	Number of Samples	Lead concentrations in milligrams per 10 cubic meters of air		
		Maximum	Minimum	Average
Mine haulage-ways	2	0.088	0.055	0.072
Working face	4	0.098	0.014	0.044

* Samples collected with electrostatic precipitator and analyzed by x-ray diffraction method.

REFERENCES

1. Schrenk, H. H. and F. L. Feicht. Bureau of Mines Midget Impinger. U.S. Bureau of Mines Information Circular 7076. 1939.

2. Bloomfield, J. J. and J. M. DallaValle. The Determination and Control of Industrial Dust. U.S. Public Health Bulletin 217. Washington, Government Printing Office. 1935.

3. Goldman, F. H. Methods for the Determination of Quartz in Industrial Dusts. U. S. Public Health Reports. 52; 1702. 1937. Reprint 1882.

4. Chamot, E. M. and C. W. Mason. Handbook of Chemical Microscopy. New York. John Wiley and Sons, Inc. 1930, p. 402.

5. Yant, W. P. and L. B. Berger. Sampling Mine Gases and Use of the Bureau of Mines Portable Orsat Apparatus in Their Analysis. U.S.Bureau of Mines Miners' Circular 34. Revised June 1936. No. 10, p. 30.

6. The Working Environment and the Health of Workers in Bituminous Coal Mines, Non-Ferrous Metal Mines, and Non-Ferrous Metal Smelters in Utah. U. S. Public Health Service and Utah State Board of Health. 1940.

7. Carbon Monoxide: Its Toxicity and Potential Dangers. U. S. Public Health Reports 56: 421. 1941.

8. Excerpt Printed by Permission of U.S.Bureau of Mines and Mining Operators of Tri-State District.

9. Dreessen, W. C. and T. I. Edwards, W. H. Reinhart, R. T. Page, S. H. Webster, D. W. Armstrong, and R. R. Sayers. The Control of the Lead Hazard in the Storage Battery Industry. Public Health Bulletin 262, Washington, Government Printing Office. 1940.

10. Fairhall, L. T. Relative Toxicity of Certain Lead Compounds. U. S. Public Health Bulletin, 253. 1940.

11. Quantitative Analysis by X-Ray Diffraction. Determination of Quartz. Bureau of Mines, R.I. 3520. June 1940.

OKLAHOMA INDUSTRIAL HYGIENE SURVEY

INDUSTRIAL HEALTH SERVICES DATA

Surveyed by: ____________

Name of Plant: ____________ Industry Code & Number: ____________ Date: ____________

Location: ____________ City: ____________ County: ____________

Plant Owner: ____________ Address: ____________ No. of Employees { M ______ F ______ T ______

Plant Official: ____________ Title: ____________

Products Mfg. or Service: ____________

SAFETY PROVISIONS

Safety Director	Full Time	
	Part Time	
Shop Committee:		
Insurance Co. Service		
Others:		

Remarks:

MEDICAL PROVISIONS

Hospital:	Company	
	Contract	
First Aid Room:		
First Aid Kit:		
Trained First Aid Worker:		

Physician:	Full Time				
	Part Time				
	On Call				
Nurse	Type	P H	R N	Oth	
	Full Time				
	Part Time				
Physical Exam.	Pre Employ				
	Periodical				

Remarks:

BENEFITS & RECORDS

Sick Benefit Org.	
Sickness Record	
Accident Record	
Occupational Disease Coverage	

Remarks:

OKLAHOMA INDUSTRIAL HYGIENE SURVEY
WORK ROOM DATA

Name of Plant: ______________ Location: ______________ Industry Code & No. ______
Department: ______________ Work Room: ______
Informant's Name: ______________ Surveyed by: ______________ Date: ______

Occupation	Number of Persons			Nature of Job	Raw Materials and By-Products	Exposure Code	Control Measures										Remarks
	M	F	T				Gen'l. Vent. Pos	Gen'l. Vent. Neg	Loc. Exh.	Enc. Proc.	Wet Meth.	Gas Mask	Respirator	Pres. Hel.	Prot. Clo.	Other	
Totals Brot. Fwd.																	
TOTAL																	